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MANUFACTURING METHODS AND TECHNOLOGY (MM AND T) MEASURE FOR FAB--ETC(U)
JUL 78 B B ADAMS, S W KESSLER, R E REED DAAB07-76-C-8120

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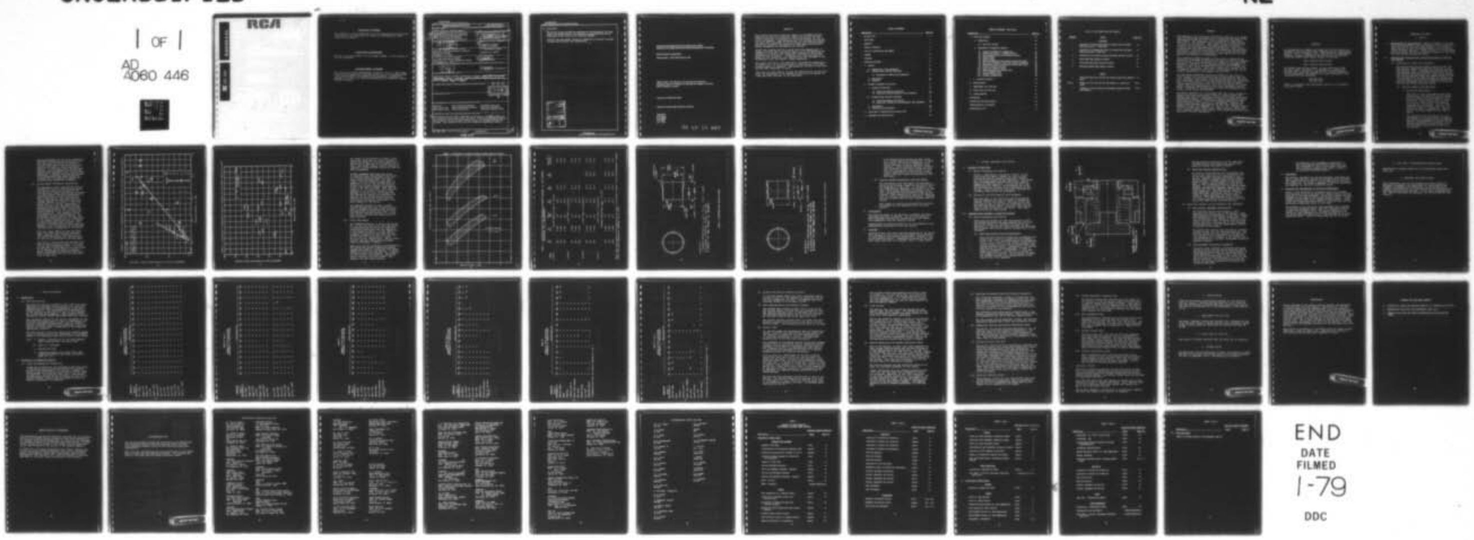

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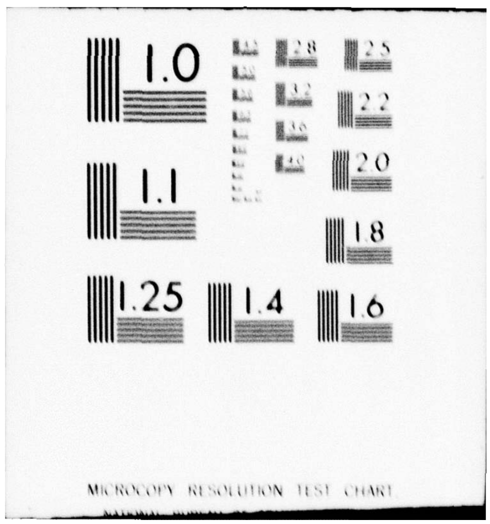
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MICROCOPY RESOLUTION TEST CHART

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DISCLAIMER STATEMENT

DISPOSITION INSTRUCTIONS

ACKNOWLEDGEMENT STATEMENT

This project has been accomplished as part of the U.S. Army (Manufacturing and Technology) Program, which has as its objective the timely establishment of manufacturing processes, techniques or equipment to insure the efficient production of current or future defense programs.

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REPORT DOCUMENTATION PAGE

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16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Thyristor	Power Switching Component	Transcalent Thyristor
High Current SCR	Power Conditioning Component	Production Engineering
Heat-Pipe Cooling	Solid State Device	Electrical Testing of SCR

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

and

This Seventh Quarterly Report describes the progress on the MM&TE program for the Transcalent (Heat-Pipe cooled) thyristors. Production engineering measures for the device and the pertinent state-of-the-art on the sample devices are included. Test results on the first pilot production samples are listed. → over

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20. (Continued)

The present status includes the submission of the Preliminary Pilot Run Report, the preparations for the production rate demonstration and the fabrication of the initial pilot production samples.

Plans for the next Quarter include the completion of the pilot run phase including the production rate demonstration.

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MANUFACTURING METHODS AND TECHNOLOGY (MM&T)
MEASURE FOR FABRICATION OF SILICON TRANSCALENT THYRISTOR

Seventh Quarterly Progress Report

Period Covered: 1 April 1978 to 30 June 1978

Object of Study: The objective of this manufacturing methods and technology measure is to establish the technology and capability to fabricate Silicon Transcalent Thyristors.

Contract No. DAAB07-76-C-8120

Approved for public release; distribution unlimited

Prepared by:
B. B. Adams
S. W. Kessler
R. E. Reed
D. R. Trout

ABSTRACT

This Seventh Quarterly Technical Report on the MM&TE Contract DAAK07-76-C-8120 for Transcalent (Heat-Pipe cooled) SCR Thyristors describes the progress on device production for the 40 Pilot Run Samples. Also described are the problems encountered and the results achieved in the testing of the numerous characteristics, including the sampling of some design and environmental parameters as required by the contract.

Actual test results for the initial Pilot Run Samples are included to verify that the device design can be successfully reproduced to conform to the electrical, mechanical and thermal specification of SCS-477. Production rate data has been prepared for the production rate demonstration and included in the Preliminary Pilot Run Report, issued separately.

The latest revision to the PERT Chart, prepared and submitted on 29 August 1977, is still applicable as the balance of the work program remains on schedule. Approximately one-half of the Pilot Run has been completed, to date.

Plans for the next quarter include the demonstration of the Pilot Line, the production of the balance of the Pilot Run Sample devices and their delivery to the government.

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PURPOSE

The purpose of this production engineering contract is to establish the technology and capability to fabricate heat-pipe cooled semiconductor power devices, silicon Transcalent Thyristors, Type J15371. The subsequent pilot production of these devices is a part of the contract. This report covers the efforts performed by the contractor in the seventh quarterly period to initiate the Pilot Run Sample Device production. Both the engineering and confirmatory samples were adequately characterized previously. Plans for future work are also presented and other pertinent information is discussed to help assure that the purpose of the contract is accomplished.

This contractual MM&TE program is being used to establish the production techniques, to establish the quality control procedures and to verify a pilot production rate capability for the J15371 thyristor, conforming to the drawing attached to AMENDMENT 1 of SCS-477 as well as to the modifications No. P00001, P00002 and P00003 to the contract. Electrical, mechanical, thermal and environmental inspections are a part of the program as well as extensive documentation requirements, per DD 1423.

No high volume production facilities existed at the start of this contract for the Transcalent type of solid-state power device. However, facilitation is being accomplished for the pilot rate requirement and higher volume production planning constitutes Step II of the contract. Thus, the time required to produce future large quantities of the J15371 will be reduced for either current military requirements or for future emergency requirements. Reduction of the reproductive costs for production quantities is also being accomplished.

The J15371 thyristor is a 400 amperes RMS, 800 volts, forced air cooled solid-state power control device, lighter weight and smaller size than the conventional devices with their externally attached heat-sinks. Ruggedness and improved reliability result from these innovations. A blocking voltage capability of 800 volts minimum at 125° Celsius is a requirement. Original R&D efforts were conducted successfully by RCA under Contract No. DAAK02-69-C-0609, for MERADCOM, Ft. Belvoir, VA. Potential applications include power conditioning, power switching, phase control, voltage variable power supply, motor speed control and other high power military equipments.

GLOSSARY

All abbreviations, symbols and terms used in this report are consistent with the Electronics Command Technical Requirements SCS-477, dated 5 December, 1974. This Technical Requirements document, in turn, references MIL-S-19500 for the abbreviations and sumbols used therein except, as follows:

V_{GR} = Reverse Gate Voltage

I_{GR} = Reverse Gate Current

The format used for this report is that specified in the DD 1423, namely, ECIPPR No. 15, Appendix C, augmented by MIL-STD-847A. Sub-section numbering is based on Appendix C and the applicable test methods are those referenced in the following military standards:

MIL-STD-750B
MIL-Std-202E

Detail, individual item requirements shall be in accordance with MIL-S-19500.

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NARRATIVE AND DATA

1. Device

a. Description of the Structure - Refer to pages 9-13 of the First Quarterly Report for a description of the Transcalent thyristor device, the applicable reports, and the applicable patents as well as the advantages of this heat-pipe cooled technical approach. Refer to Figure 1 in the Second Quarterly Report for the cross-section drawing of the J15371 with the external dimensions added.

b,c. Defining the Problem Areas and Work Performed to Resolve the Problem

(1) Conversion of Design for Production

The Transcalent Thyristor design achieved under R&D Contract No. DAAK02-69-C-0609 was described in the FTR, October, 1972. Subsequent refinements have been incorporated under Contract N62269-73-C-0635 and by RCA funded engineering projects. Additional engineering has been applied under this MM&TE program to convert the design to one more suitable for production, as described in prior Quarterly Reports covering the period 27 September 1976 to 31 March 1978 and below for the most recent quarterly period.

(a) Item No. 0001AC Pilot Run Phase

i. SCR Device Fabrication

The first 35 Pilot Run samples were fabricated during this quarterly report period. To date, twenty-six have passed the 100% basic electrical tests of Table I, Group A in SCS-477. Seven devices are awaiting test and two have failed, as allowed by paragraph 4.7 of SCS-477. This is a 93% yield for those 28 devices that have completed the Table I inspections. Refer to Section 5 of this report for the test results.

The remaining Pilot Run devices will be fabricated in the next quarter to complete the contract requirement of 40 deliverable devices. These additional devices will be used to demonstrate the production rate, as required by Section F49 of Part II of the contract.

Parts procurement for the pilot production has been initiated by the Production Control Activity, as previously reported. Initial quantities of key parts have been received and found to be of acceptable quality. A continuing effort by the above activity will be required to maintain our present pilot production rate and delivery commitment. Although some shortages exist, it is anticipated that vendor parts deliveries will be adequate to support the on-going pilot production schedules.

ii. Silicon Wafer Processing Correlations

The dependency of the exponential rate of voltage rise, dv/dt, upon the wafer shunting current (which was reported in the last quarterly report and plotted in Figure 2 of that report) has been extrapolated to greater shunting current values during this report period. Both the data previously reported and the latest data are plotted together in Figure 1. The dv/dt values are at a junction temperature of $125^{o}C$ and with a one ohm shunt resistor between the gate and cathode electrodes. The shunting currents are control parameters measured on the silicon wafers before metalizing. This parameter cannot be measured on the finished device. The previously reported data is prefixed with an "F" while the latest data is identified by the symbols identifying the lot number in which the wafers were diffused. The method of identifying the plotted data was changed to see if there was any correlation with the time of processing of the wafers.

With the larger amount of data now available, the trend line has been replotted with a smaller slope. Note that all of the latest devices meet the specification of 100 v/μs at $125^{o}C$ with a one ohm shunt.

The dv/dt at $125^{o}C$ versus the shunting current is also plotted in Figure 2, but without the one ohm resistor shunt, i.e. with an open gate. While there is no clear trend as to the data as was shown in Figure 1, nearly two-thirds of the devices exhibit a dv/dt greater than the 100 v/μs spec., even with an open gate.

Figure 1 Correlation of Exponential Rate of Voltage Rise and Wafer Shunting Current

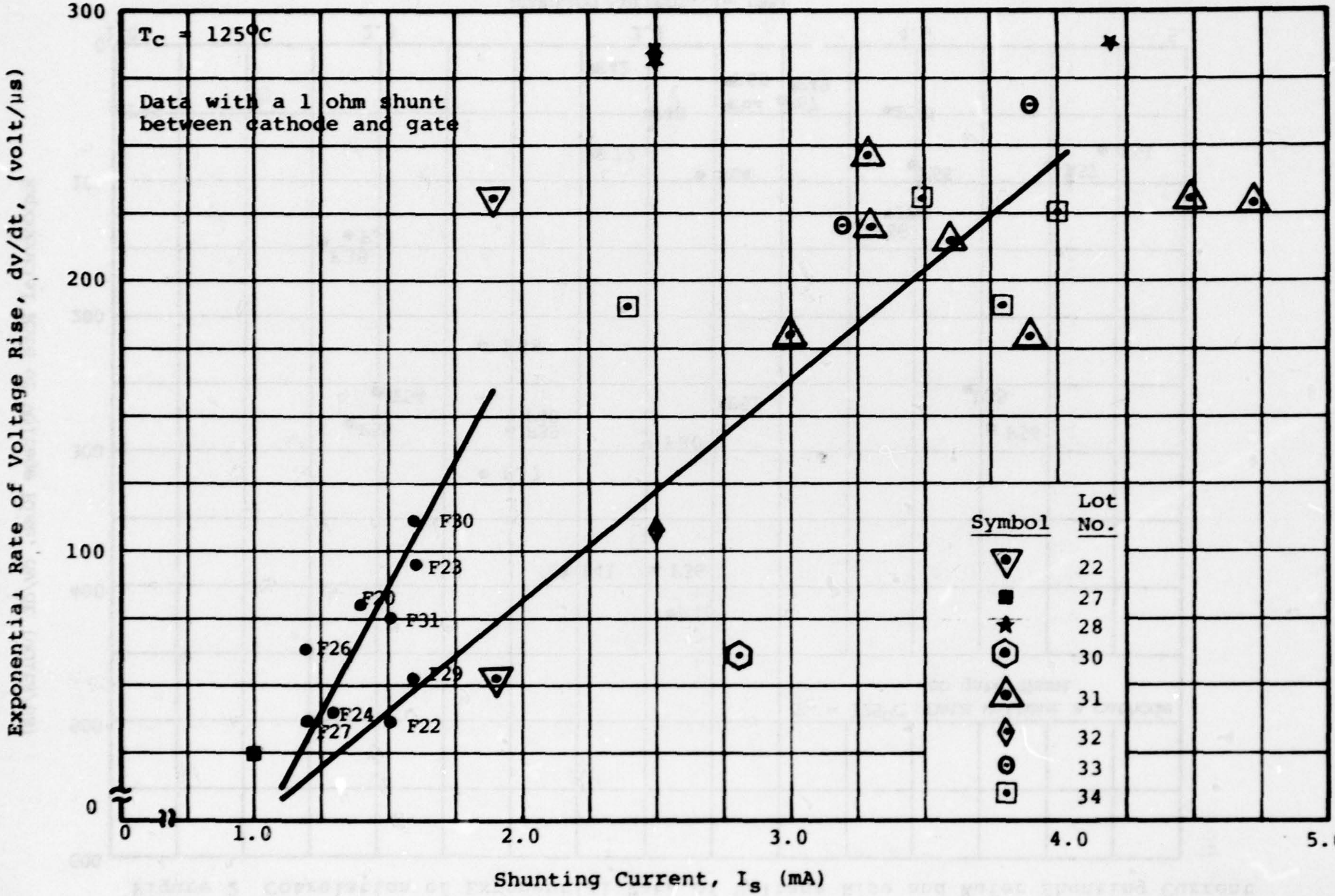
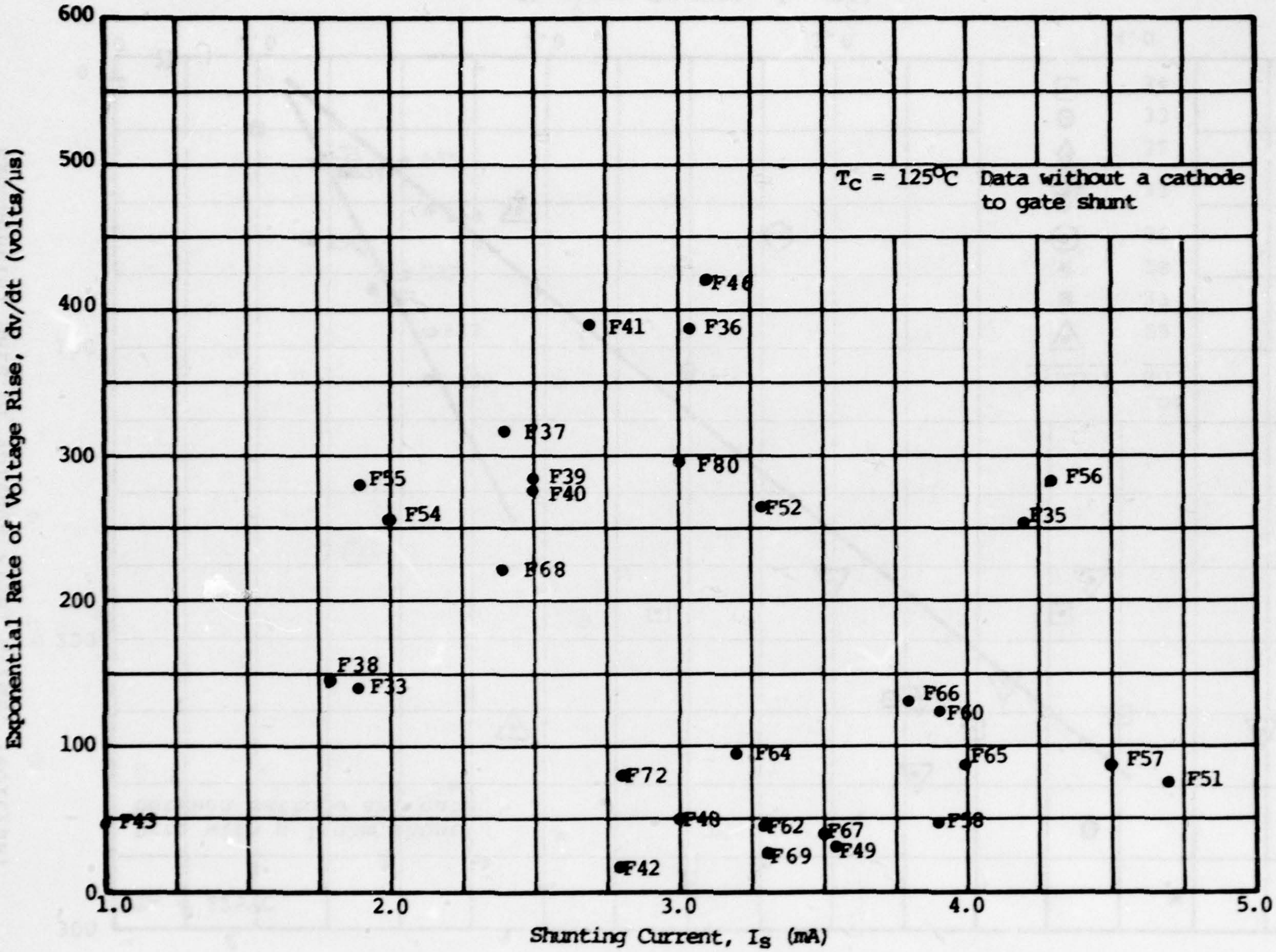


Figure 2 Correlation of Exponential Rate of Voltage Rise and Wafer Shunting Current



The lack of a correlation in Figure 2 indicates that there must be another parameter which contributes to the dv/dt capability of the device in addition to the shunting current. The slight leakage current through an imperfect silicon dioxide insulating layer is such a parameter.

Another parameter which has been noted to correlate with the diffused wafer shunting current during processing is the on-state forward voltage drop. The small signal, on-state forward voltage drop (as measured at test on the finished device) versus the shunting current is plotted in Figure 3 for three different case temperatures of 0^{o}, 80^{o} and $130^{o}C$. This data was gathered at an on-state current of four amperes, a current value low enough that the dissipative heating is negligible and that all of the voltage drop can be assumed to be across the silicon chip and none due to the contact resistance of the metal members of the device.

The observed increase in this on-state forward voltage drop with the shunting current is because the p-base width has been diffused wider to enable the wafer to conduct greater shunting currents at a potential of one volt and thus desensitize the gate electrode.

iii. Yield Improvement

The unexpected failure of device, Serial No. F37, at the $25^{o}C$ below zero test has caused a reconsideration of the strain isolation convolution previously used and removed as a cost reduction effort. A test sample of a convoluted thyristor heat-pipe was successfully tested at not only $25^{o}C$ but also at $55^{o}C$ and $70^{o}C$ below zero for three, and five cycles, respectively. The on-state voltage test data associated with these tests is displayed in Table 1.

Based upon the low temperature performance of the convoluted design, production drawing changes were made to incorporate this design change into the Pilot Run devices. A blank isolation sleeve was designed. See Figure 4 for the drawing from which the convoluted strain isolation ring was formed. See Figure 5 for the latter drawing.

Figure 3 Correlation of On-State Voltage and Wafer Shunting Current

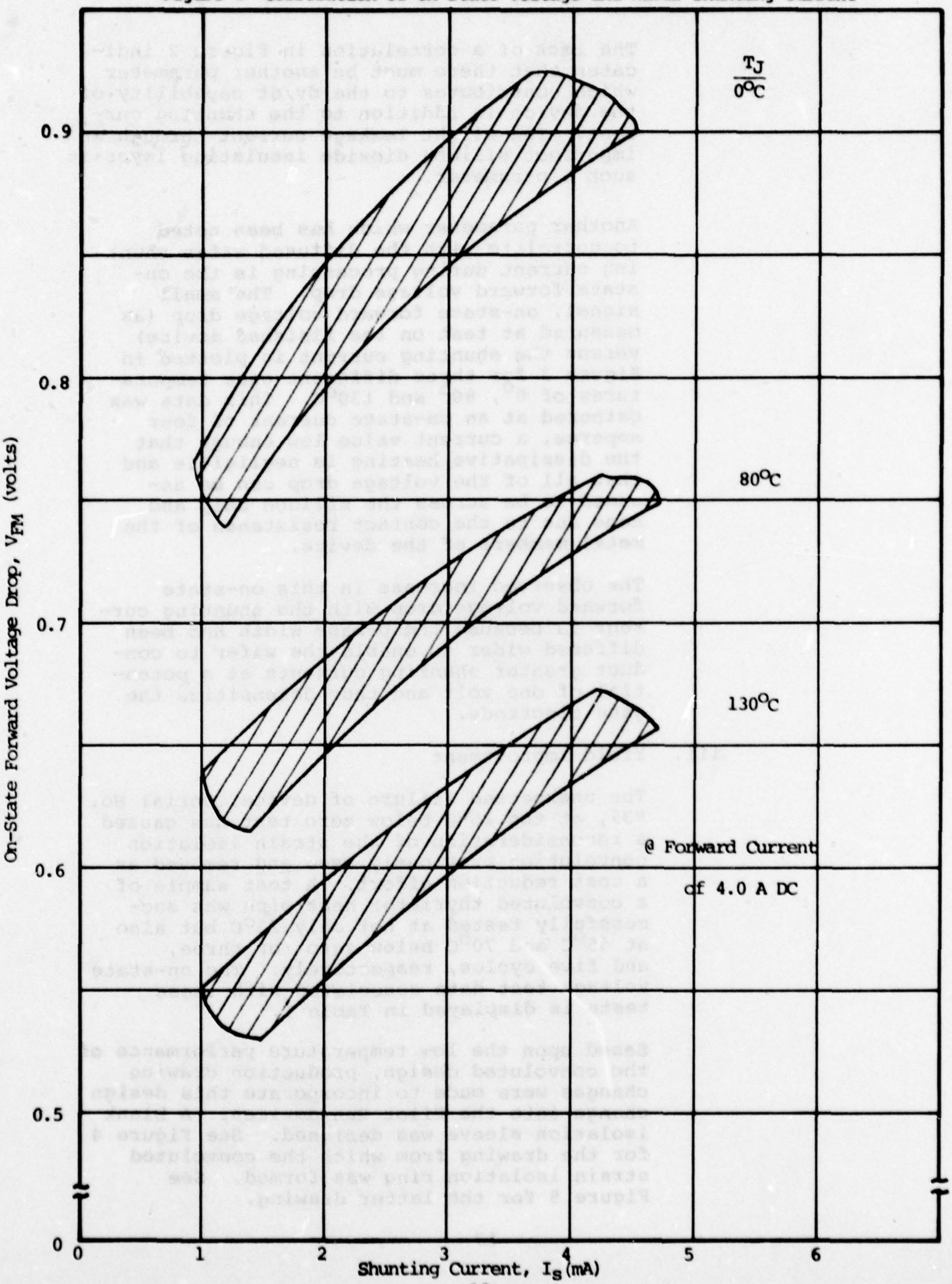
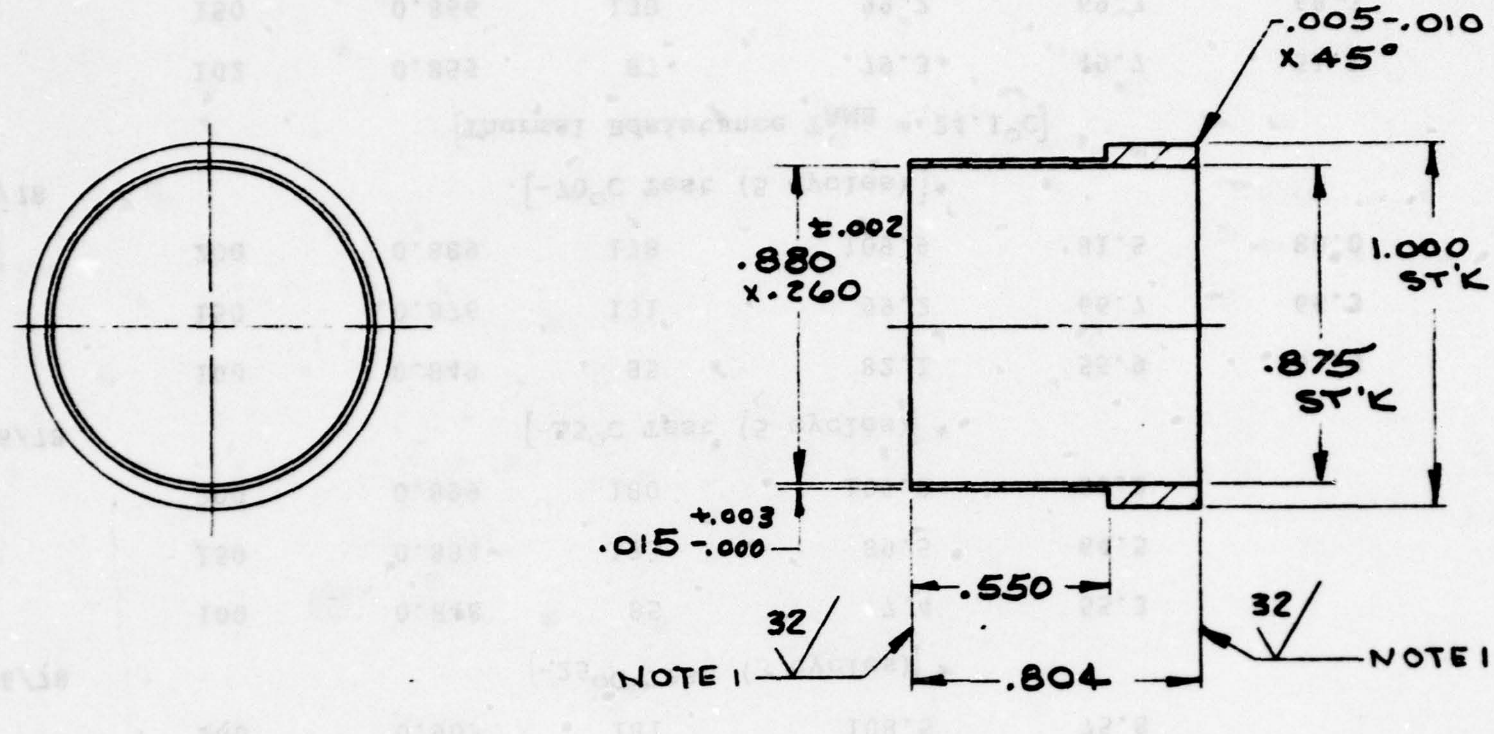


TABLE 1 CONVOLUTED HEAT-PIPE THYRISTOR ON-STATE VOLTAGE, V_F, AND THERMAL RESISTANCE, θ_{J-C}, MEASUREMENTS

Date	I_F (A)	V_F (v)	P_{diss} (w)	T_J (^oC)	T_K (^oC)	T_A (^oC)	θ_{J-C}(Av.) (^oC/w)
5/26/78	[24.3^{o}C Control Test (1 cycle)]						
	100	0.854	85	80.0	50.0		0.44
	150	0.881	132	99.7	63.3		0.28
	200	0.903	181	108.5	75.8		0.18
5/26/78	[-25^{o}C Test (3 cycles)] *						
	100	0.848	85	77.4	55.3		0.26
	150	0.884	133	89.5	64.5		0.19
	200	0.899	180	105.2	80.2		0.14
5/26/78	[-55^{o}C Test (5 cycles)] *						
	100	0.849	85	82.1	55.9	53.0	0.33
	150	0.876	131	99.2	66.7	66.3	0.25
	200	0.889	178	109.9	81.5	80.0	0.16
6/6/78	[-70^{o}C Test (5 cycles)]*						
	[Thermal Resistance T_{AMB} = 24.1^{o}C]						
	102	0.855	87	79.3	49.7	51.1	0.33
	150	0.866	130	99.2	69.7	68.3	0.23
	200	0.886	177	111.7	83.2	80.3	0.17

*Each cycle consisted of the application of 250 A of average current in the environmental chamber until the case temperature reached +25 to +40^{o}C.



NOTES:
1. ENDS PERPENDICULAR TO ℄ T.I.R = .005
2. CLEAN COPPER PER W614D
3. PART TO BE FREE OF BURRS

Figure 4 Blank Heat-Pipe Isolation Sleeve

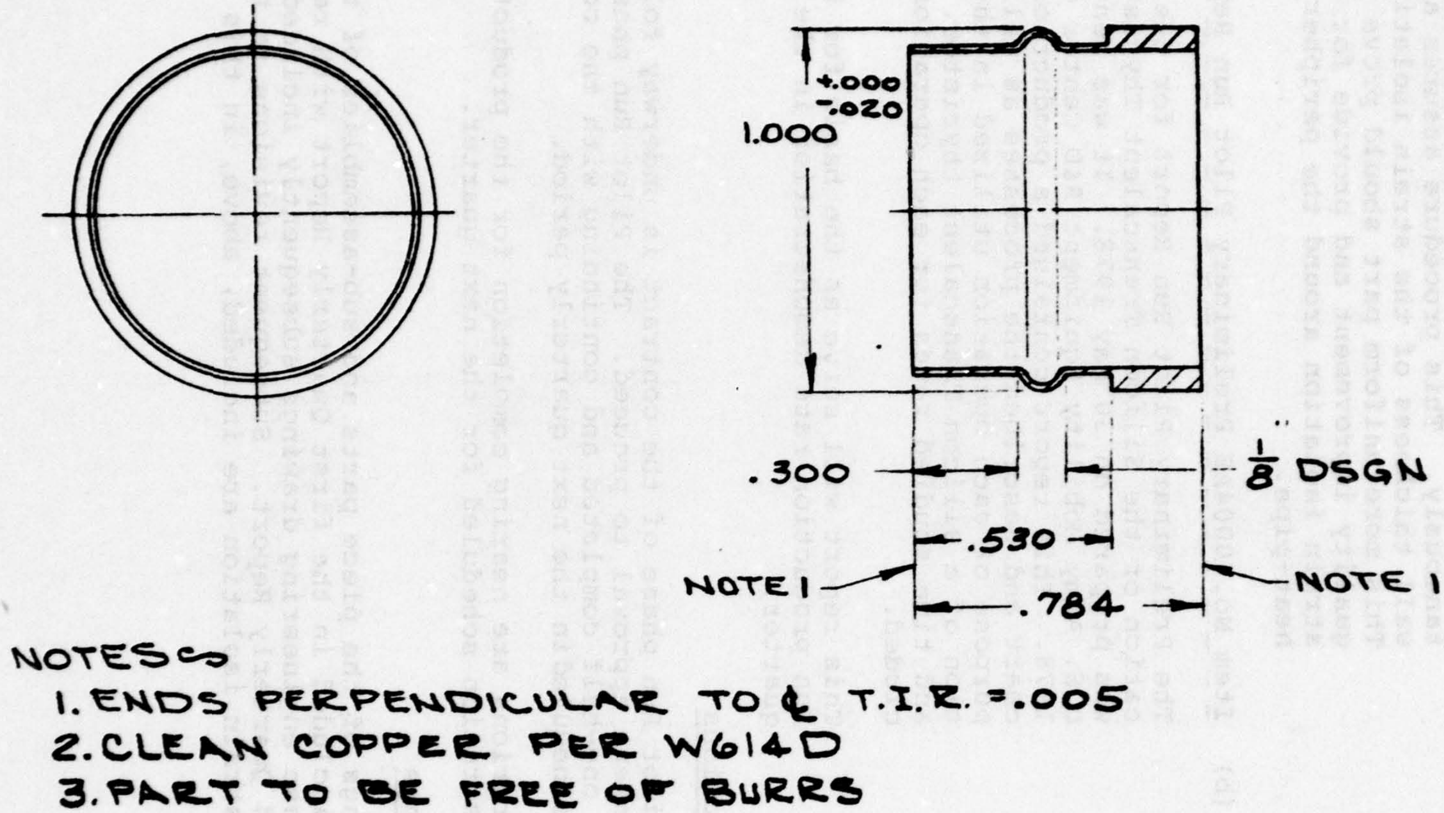


Figure 5 Convoluted Heat-Pipe Isolation Sleeve

A new fabrication procedure has been found, via a vendor search for suggestions, in which the internal and external diameters of the strain isolation rings are machined simultaneously. This procedure assures a constant wall thickness of the strain isolation ring. This more uniform part should prove to be a quality improvement and provide for uniform strain isolation around the periphery of the heat-pipe.

(b) Item No. 0004AE Preliminary Pilot Run Report

The Preliminary Pilot Run Report for the Fabrication of the Silicon Transcalent Thyristor J15371 was prepared on 30 May 1978. It was sent to the U.S. Army Mobility Equipment R&D Center on 14 June 1978. This report contained a production flow chart and described the processes as well as the purpose of each operation utilized in the fabrication of a silicon Transcalent thyristor. Drawings and time studied rates for each operation were included.

This report will serve as the basis for the Pilot Run production rate demonstration in the next quarter.

d. Conclusions

The Pilot Run phase of the contract is underway following government approval to proceed. The Pilot Run phase is about one-half completed and continuing with the completion scheduledin the next quarterly period.

Preparations are nearing completion for the production rate demonstration scheduled for the next quarter.

e. Drawings

Drawings of the piece parts and sub-assemblies of the device were included in the first Quarterly Report with revisions to these engineering drawings subsequently included in the Second Quarterly Report. Subsequent revisions to the heat-pipe strain isolation are included, above, in this report.

2. Process, Equipment and Tooling

a. Purpose of Each Step

(1) Device Processing and Tooling

Figure 4, Engineering Drawing No. 3025577, in the First Quarterly Report, showed the flow of parts through the various assembly steps and a descriptive title was listed for each operation. Also shown were the subassembly drawings and fixture drawing numbers for each operation. In both the First and Second Quarterly Reports, the procedures for using the fixtures were included with a photograph of each fixture. This information continues to be used for the device fabrication and processing.

(2) Electrical and Environmental Test Equipment

The flow chart of the electrical and environmental testing sequence was given in Figure 7, Drawing No. 3025578, of the First Report. The name of the test was given as well as the special conditions and the MIL-STD-750B method number. Long-time tests had the time interval indicated in the figure. This chart remains valid for the program.

b,c. Problem Areas and Work to Resolve Problems

(1) Device Processing and Tooling

Fabrication processes that were determined to limit the production quantities were improved for the Pilot Run by the yields, by increasing the quantity per operation, by reducing the labor required, by improving the fixtures, and by more complete documentation of the processes.

(a) Heat-Pipe Brazing Fixture Improvement

After brazing, several cathode body assemblies were noted to be canted with respect to the assembly center line. This noticeable defect was determined to be a direct result of the operator handling procedures normally encountered in the hydrogen, push through brazing furnace. Consequently, one cathode body brazing fixture was modified, as shown in Figure 6 (Drawing No. A-3025290R4). A ring was added which tends to lock the top and bottom fixture components together. This procedure protects the assembly against jolts perpendicular to the center line of the assembly.

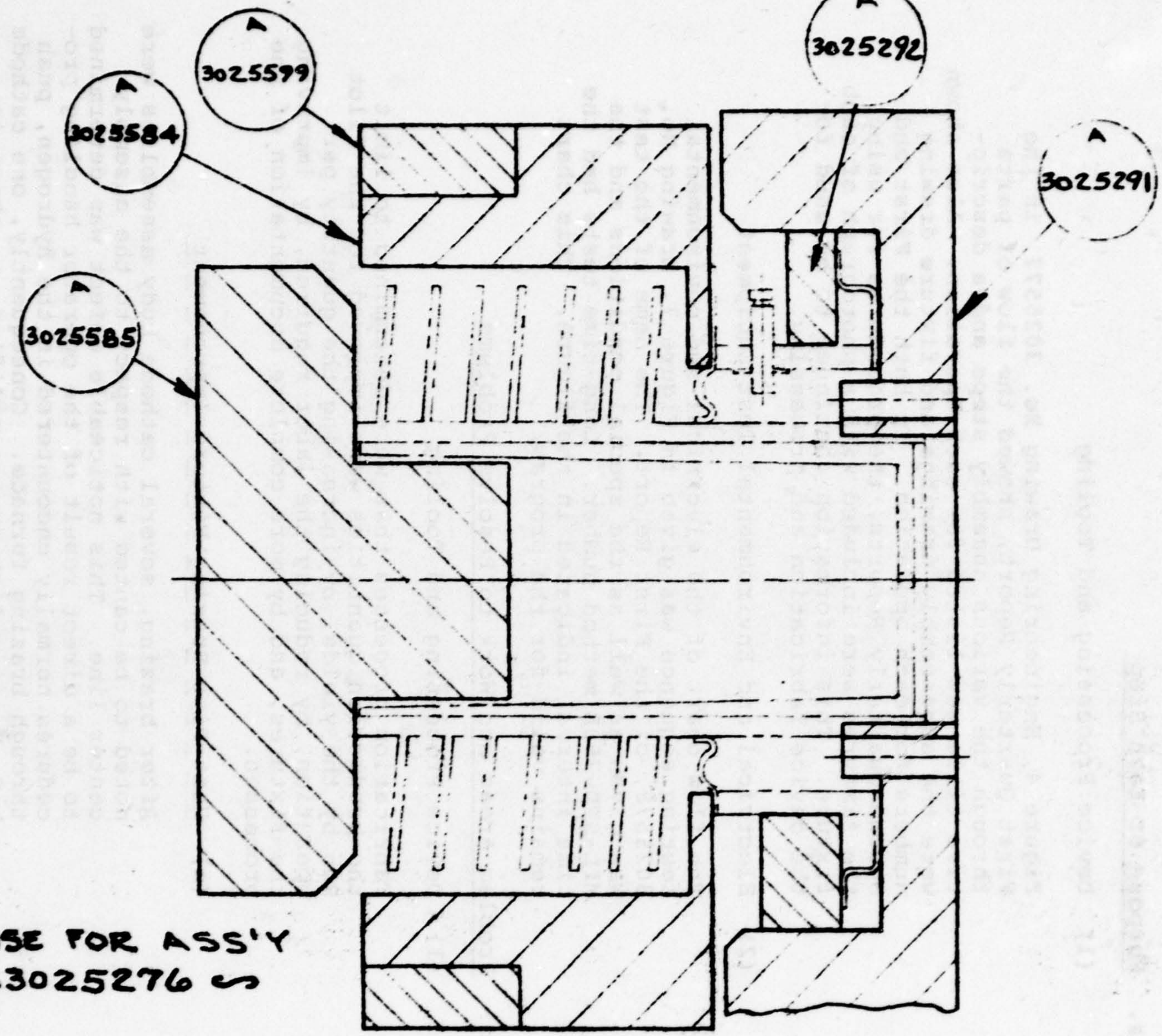


Figure 6 Modified Cathode Body Brazing Fixture

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The new concept worked well, and the same modifications of all of the existing cathode body brazing fixtures have been initiated.

(b) Heat-Pipe Lapping Mechanization

An on-going investigation into the machine lapping of the discs that form the evaporator ends of the heat-pipes has been completed in this period. Superior flatness and surface finishes were obtained on samples lapped at the machine vendor's plant. By procurement of this equipment, a labor-intensive operation could be eliminated. In consultation with the outside vendor, lapping carriers were designed, tested, and refined to fit both the anode and the cathode heat-pipe assemblies. Eight Transcalent thyristor units have been fabricated, thus far, via the vendor's lapping machines and these custom carriers. This same approach will be utilized on a larger population of heat-pipes in the next period for more of the Pilot Run devices.

(2) Electrical Thermal and Environmental Test Equipment

(a) Gate Trigger Equipment Construction

The Pilot Run device tests require a -25^{o}C inspection for 100% of all of the devices. This test includes the measurement of the gate trigger characteristics at the reduced temperature. Since the environmental test chamber is located in an area of the plant which is remote from the Transcalent test area, a second set of test equipment was fabricated to allow the simultaneous testing of devices in both areas.

The second test station also utilizes an integral holding current test and optimized metering. The metering system has been compared favorably with the accurate digital laboratory meters and new test equipment will be added to the computer controlled calibration schedule, described in previous Quarterly Reports.

(b) Test Equipment Calibration Schedules

Electrical test equipment calibration dates were listed in Table 4 of the Fourth Quarterly Report. The schedule established for the recalibration of these equipments on a regular basis was used to recalibrate each equipment in this report period. This call-out occurs automatically at four to six months intervals. The calibration was carried out by the RCA Meter Laboratory Calibration and Standards Department.

Environmental test equipment calibrations in the RCA-Lancaster Environmental Laboratory are also performed at four to six months intervals. The calibration schedule was listed in Table 5 of the Fourth Quarterly Report.

d. Conclusion

The process, equipment and tooling designed, fabricated and used to fabricate and evaluate the engineering and confirmatory sample devices is now in use for fabricating the Pilot Run production. No process, equipment or tooling limitations are apparent for the pilot production phase.

e. Drawings and Photographs of Tooling and Equipment

Copies of the drawings of the special tools and fixtures were included in the First Quarterly Report along with Block Diagrams of the test equipment. Tools and fixtures that were revised were included in the Second Quarterly Report. Photographs of these items were included in both reports. These tools and fixtures are being used for the Pilot Run with the modification described above in this report.

Photographs of the electrical test equipment were included in the Third Quarterly Report with text references that described each equipment item. Testing procedures for the electrical test equipment were included in Appendix C of the Second Quarterly Report and in the Appendix of the Third Quarterly Report. These are being used for the Pilot Run.

3. Flow Chart of Manufacturing Process Yield

Manufacturing process yields are to be determined during the Pilot Run.

4. Equipment and Tooling Costs

This information will not be included since such a data requirement is generally not applicable to a Firm Fixed Price Contract on equipment and tooling that is purchased and furnished by the contractor for unrestricted use in fabricating the devices required by the contract or for other government end use. RCA is furnishing the equipment and tooling used for this contract.

5. Data and Analysis

a. Inspections

(1) Pilot Run Devices

The Pilot Run devices included in this report are being inspected in accordance with paragraph 4.5, using the sampling plan included in this paragraph of the specification SCS-477. The requirements of paragraphs F.49 of the contract as well as 3.1.6 and 3.1.10 of ECIPPR No. 15 are also being observed. Specification modifications No. P00001, P00002 and P00003 have been included.

The evaluation testing of the initial candidates for the Pilot Run requirement began in April in accordance with the Test Plan submitted previously (SLIN No. 0005AA). Specific comments, analyses and discussions of the test results are listed below, categorized by the inspection sub-groups in SCS-477.

The test results of the first thirty-four devices tested within this report period are summarized in the attached Tables 2. The following codes are utilized in the tables.

Code: P - passed, including all of the final measurements required after each major test.

IP - Test is in progress.

F - Failed this test.

A - Acceptance judged from another Pilot Run sample submitted to this test; per SCS-477, para. No. 4.5.

b. Discussion of Inspection Results

(1) Visual and Mechanical Inspections

Inspection of device No. F35 disclosed a hair-line crack in the high-voltage ceramic and the device, although operable, was considered to be rejected. However, this device passed all of Group A and a portion of the Group B inspections, including the surge test. This device failure along with the failure of device No. F43 (to be discussed below) comprise the two allowed failures at Group A, Sub-Groups 1-4 inspection.

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TABLE 2a

SUMMARY OF PILOT RUN DEVICES
PERFORMANCE vs. SPECIFICATIONS

Inspection	Device Serial No.																
Group A, Sub-Groups 1-4	F33	F35	F36	F37	F38	F39	F40	F41	F42	F43	F46	F48	F49	F50	F51	F52	F54
Vis. & Mech.	P	F	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
i_{RBOM} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
i_{FBOM} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
I_H @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
i_{RBOM} @ 125°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
i_{FBOM} @ 125°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
V_{GT} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
I_{GT} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
V_{GT} @ 125°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
I_{GT} @ 125°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
dv/dt @ 125°C	P	P	P	P	P	P	P	P	P	F	P	P	P	P	P	P	P
t_{OFF} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
V_{FM} @ T_c = 100°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P

TABLE 2a (cont.)

SUMMARY OF PILOT RUN DEVICES
PERFORMANCE vs. SPECIFICATIONS

Inspection	Device Serial No.																
Group A, Sub-Groups 1-4	F55	F56	F57	F58	F60	F62	F63	F64	F65	F66	F67	F68	F69	F71	F72	F75	F76
Vis & Mech.	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
i_{RBOM} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
i_{FBOM} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
I_H @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
i_{RBOM} @ 125°C	P	P	P	P	P	P		P	P	P	P	P	P	P	P	P	P
i_{FBOM} @ 125°C	P	P	P	P	P	P		P	P	P	P	P	P	P	P	P	P
V_{GT} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
I_{GT} @ 25°C	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
V_{GT} @ 125°C	P	P	P	P	P	P	P	P	P	P	P	P	P	IP	P	P	P
I_{GT} @ 125°C	P	P	P	P	P	P	P	P	P	P	P	P	P		P	P	P
dv/dt @ 125°C	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P
t_{OFF} @ 25°C	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P
V_{FM} @ T_C = 100°C	P	P	P	P	P	P		P	P	P	P	P	P		P	P	P

TABLE 2b

SUMMARY OF PILOT RUN DEVICES
PERFORMANCE vs. SPECIFICATIONS

Inspection	Device Serial No.																
Group B, Sub-Groups 1-4	F33	F35	F36	F37	F38	F39	F40	F41	F42	F43	F46	F48	F49	F50	F51	F52	F54
I_{FM} (Surge)	A	P	A	P	F	A	A	A	P		A	A	A	A	A	A	A
θ_{jc}, Initial	P	P	P	P	P	P	P	P	P	P	P	F	P	P	P	P	P
V_{GT} @ -25°C	P	P	P	P		P	P	P	P	P	P	P	P	P	P	P	P
I_{GT} @ -25°C	P	P	P	P		P	P	P	P	P	P	P	P	P	P	P	P
V_{FM} @ -25°C	P	P	P	F		P	P	P	P	P	P	F	P	P	P	P	P
Thermal Shock	P		A			A	A	A	A		P		A	A	P	A	A
Moisture Resistance	P		A			A	A	A	A		P		A	A	P	A	A
Block. V. Life Test @ 125°C	A		P			A	A	A	P		A		A	A	IP	A	A

TABLE 2b (cont.)
SUMMARY OF PILOT RUN DEVICES
PERFORMANCE vs. SPECIFICATIONS

Inspection	Device Serial No.																
Group B, Sub-Groups 1-4	F55	F56	F57	F58	F60	F62	F63	F64	F65	F66	F67	F68	F69	F71	F72	F75	F76
I_{FM} (Surge)	A	A	P	A	A	A		A	A	A	A	A	A		A	A	A
θ_{jc}, Initial	P	P	P	P	P	A		P	P	P	P	P	P		IP	IP	IP
V_{GT} @ -25°C	P	P	P	P	P	P		P	P	P	P	P	IP				
I_{GT} @ -25°C	P	P	P	P	P	P		P	P	P	P	P					
V_{FM} @ -25°C	P	P	P	P	P	F		F	P	F	P	P					
Thermal Shock	A	A	A	A	A				A		A	A					
Moisture Resistance	A	A	A	A	A				A		A	A					
Block. V. Life Test @125°C	A	A	A	A	A				A		A	A					

TABLE 2c

SUMMARY OF PILOT RUN DEVICES
PERFORMANCE vs. SPECIFICATIONS

Inspection Group C, Sub-Groups 1-5	Device Serial No. F33	F35	F36	F37	F38	F39	F40	F41	F42	F43	F46	F48	F49	F50	F51	F52	F54
Physical Dimen.	P	P	P	P	P	P	P	P	P		P		P	P	IP	IP	IP
Shock	A		A			A	A	A	A		A		A	P			
Vibration	A		A			A	A	A	A		A		A	P			
Constant Accel.**	A		A			A	A	A	A		A		A	A			
Barom. Press. Reduced	A		A			A	A	A	A		A		P	A			
Salt Atmos.	A		A			A	A	IP	A		A		A	A			
Thermal Fatigue	A		A			P	P		A		A		A	A			
θ_{jc}, Final	P		P			P	P		P		IP		P	P			
Isothermal Charact.	P	P	P			P	P	P	P		P		P	P	P	P	P

**Information only test, per contract paragraph F3, item 7.

TABLE 2c (cont.)

SUMMARY OF PILOT RUN DEVICES
PERFORMANCE vs. SPECIFICATIONS

Inspection	Device Serial No.																
Group C, Sub-Groups 1-5	F55	F56	F57	F58	F60	F62	F63	F64	F65	F66	F67	F68	F69	F71	F72	F75	F76
Physical Dimen.	P	IP	IP	P	P				P		IP	IP					
Shock	P			A	A				P								
Vibration	P			A	A				P								
Constant Accel.**	A			A	A				A								
Barom. Press. Reduced	A			P	A				A								
Salt Atmos.	A	IP		IP	IP				A								
Thermal Fatigue	A				P				A	P							
θ_{jc}, Final	P								IP								
Isothermal Charact.	P	P	P	P	P	P	F	P	P	P	P	P	P	P	P	P	P

**Information only test, per contract paragraph F3, item 7.

(2) Forward and Reverse Blocking Currents

All devices passed these tests with a maximum blocking current of only 16.5 mA recorded for device No. F41 at the high temperature of 125°C. The maximum specified blocking current is 60 mA peak at 125°C

(3) Gate Characteristics and Holding Currents

The average gate trigger current of all of the Pilot Run devices tested, to date, was only 330 mAdc at 25°C. The specified maximum value is 1000 mAdc for this test. The extremes measured were a low of 87 mA for device No. F63 and a high of 970 mA for device No. F46.

The holding currents average about 11.5 mAdc with this parameter ranging from 2.8 mA to 22 mA for all of the devices tested. The maximum specified value is 500 mAdc.

(4) Dynamic Tests

All devices passed the Exponential Rate of Voltage Rise (dv/dt), Turn-Off Time and On-State Voltage tests with the exception of device No. F43 which measured only 57 volts per microsecond of dv/dt. The specified minimum value is 100 volts per microsecond.

This parameter is influenced largely by the gate trigger current level of each device but for production control purposes, a more sensitive parameter has been found in the "shunting current" (I_s) measurements taken earlier in the fabrication sequence of the wafer as a control parameter during the diffusion processing.

This I_s value is a measurement of the gate p-region resistivity which varies with the junction depth diffused into the wafer. Device No. F43 measured a lower shunting current than the other devices measured during the Pilot Run. It should be noted that a lower I_s value, in general, also results in a lower gate current for the device and a lower dv/dt value, even at room temperature. As more data is taken, limits will be proposed on this I_s parameter for improved overall production yield of future devices.

The Turn-Off Time parameter was measured on 100% of the devices. The results ranged from a maximum of 68 μsec to a minimum of 12 μsec., which is near the lower limit of the measuring equipment utilized. The maximum specified value is 150 μs.

The On-State Voltage was measured and found to have an average of 1.26 volts with very little deviation from this bogie value. The maximum specified value for this parameter is 2.0 v. The Pilot Run results thus are approximately the same as those reported for the confirmatory samples.

(5) Surge Current

Two devices, Nos. F42 and F57, have passed the 4000 amperes peak, 10-surge test. Two additional devices will be selected at random from later devices to complete this 10%-inspection requirement.

During the course of testing, a total of five devices were subjected to the Surge Current Test. The first two devices were No. 35 which was rejected for a cracked ceramic (as discussed above) and device No. F37 which later failed the 25°C below zero test. However, both devices had passed the Surge Current Test requirements. The third device, No. F38, failed during the Surge Current Test. It should be noted that the operator performed this test without engineering supervision and it is suspected that some of the surges were repeated immediately without waiting for the specified one minute time interval to elapse.

(6) Reduced Temperature and Thermal Resistance Tests

Most of the devices, to date, have been inspected for gate trigger characteristics and on-state voltages at a case temperature of 25°C below zero. All but five of the devices, Nos. F37, F48, F62, F64 and F66, passed this test. The failures were mechanical although the electrical performance was within the specified limits during the test. All five devices will be replaced in the program. Data have been included on all of the devices tested for statistical purposes.

The failure analysis and the corrective action to be taken are discussed elsewhere in this report.

Thermal Resistance data was recorded preceeding this -25°C test and then some time afterwards to verify the successful completion of the -25°C conditions. Of the eight devices retested for this parameter, the thermal resistance showed a slight improvement after the 25°C below zero tests, the same as reported previously for the confirmatory samples. The maximum specified value of thermal resistance is 0.15°C per watt.

(7) Heat-Pipe Isothermal Tests and Physical Dimensions

All 30 devices measured, to date, to verify that the heat-pipes are isothermal in operation were well within the recommended differential temperature across each heat-pipe, except for one device, Serial No. F63. A marginal 10°C difference in the anode heat-pipe temperatures exceeded the 8°C recommendation and this device was slated for reprocessing.

Non-isothermal heat-pipes can be salvaged with a high degree of success by reprocessing. This procedure will be attempted on unit F63 in the next report period.

For the sixteen devices measured, to date, the physical dimensions measured well within the tolerances allowed.

(8) Temperature Cycling and Moisture Resistance Tests

Devices No. F33 and F46 both were subjected to the 10% sampling tests and have passed satisfactorily. F33 was then placed on the shelf as a completed device whereas F46 requires the final thermal impedance test, yet. Two additional devices will be selected for these tests later in the program.

(9) Blocking Voltage Life Test

Devices No. F36 and F42 have successfully completed the 500 hours minimum time at 800 peak forward and reverse volts with the specified 125°C case temperature. A single oven facility is being used for this test and, therefore, the devices are tested sequentially. A strip chart recorder was utilized to monitor the blocking current throughout the 500 hours period for device No. F42. This blocking current diminished from 19 mA to only 6 mA within the first 200 hours and remained at the lower level for the balance of the test. Device No. F51 is scheduled for this test next and the 500 hours should be completed by the second week of July, 1978. The final device for this test is scheduled for completion in the first week of August, 1978 as the final 10% sample.

(10) Shock and Vibration Tests

Three devices, Serial No. F50, F55 and F65, have completed these two environmental tests satisfactorily. Device No. F67 is scheduled for these tests in mid-August 1978 to complete the 10% sample.

(11) Reduced Barometric Pressure Test

Two devices, Serial Nos. F49 and F58, were tested for one minute at 15 mm of mercury pressure with 800 volts of applied forward and reverse voltages. There was no evidence of corona and no deterioration of the device characteristics. Two more devices will be selected at random later in the program to complete the 10% sample size required for this test.

(12) Salt Atmosphere Test

Four devices were selected to be given the 24 hour Salt Atmosphere Test as per MIL-STD-750, Method 1041.1. These devices are Ser. Nos. F41, F56, F58 and F60. The test will be performed in-house with a newly purchased salt spray chamber and is scheduled for completion by mid-August.

(13) Thermal Fatigue Test

Thyristors Nos. F39, F40, F60 and F68 have undergone this test sequence according to the requirements of paragraph 4.6.2 of SCS-477. The gate voltage and current trigger levels remained the same and the forward and reverse blocking currents in the units improved substantially from the aging applied by this test. The on-state voltage also showed a slight improvement. These four devices complete the 10% sample requirement.

(14) Constant Acceleration Test

This "information only" test was performed on four total devices in both the engineering and confirmatory sample phases of the contract. This test will thus not be repeated during the Pilot Run phase. Results were listed in previous Quarterly Reports.

c. Corrective Action

Previously reported corrective actions have proven successful in securing a reproducible thyristor device with consistently good electrical, thermal, mechanical and environmental characteristics. The results listed above are believed to verify this conclusion.

Only the 25^{o}C below zero test appears to require any further corrective action to improve the yields. Note, however, that 22 of the 27 devices tested have passed that severe test. This is an 81½% yield, to date.

RCA is thus confident of being able to successfully complete the Pilot Run phase of the contract on schedule.

6. Specification

There are no further modifications proposed for the specification No. SCS-477. RCA has verified thus far in the Pilot Run that the Transcalent thyristors fabricated during this phase of the contract are meeting all of the requirements of the specification.

7. Requirement for Pilot Run

The space, manpower, facilities, tooling, etc., required for the Pilot Run were listed in the Preliminary Pilot Run Report, dated 30 May 1978, and submitted separately as Contract Data Item No. 0004AE.

8. Total Cost for Pilot Run

Cost data will become available when the Pilot Run is completed.

9. Program Review

The PERT Chart revision submitted 29 August 1977 remains in effect showing the Pilot Run with the delivery of the devices scheduled for late in September, 1978. The program is on schedule.

CONCLUSIONS

Effort expended in the seventh contract quarter was successful in starting the Pilot Run Samples. Verification on the Confirmatory Samples that the design meets all of the specifications adds assurance that the Pilot Run phase will be successful. Time studies have been used to verify the required production rate capability exists on almost all of the work stations. Where required, increases in capacity are being made at the few limiting work stations, to bring them up to the required pilot production rate. RCA is thus confident of meeting the full MM&TE specification requirements for the Pilot Run devices. Both improved wafers and improved packages will be fabricated for these devices.

The program is proceeding in accordance with the latest revised PERT Chart, dated 29 August 1977. Approximately one-half of the Pilot Run devices have been completed, to date.

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PROGRAM FOR THE NEXT QUARTER

1. Continue to issue the monthly reports, as required by DD 1423,
2. Demonstrate the Pilot Run production rate, and
3. Complete the Pilot Run device fabrication and evaluation tests.

IDENTIFICATION OF PERSONNEL

The professional and skilled technical personnel who are actually working on the MM&TE project during the first seven quarters of the contract have varied backgrounds, as listed in the biographical resumes included in the previous Quarterly Reports. No additional resumes are included in this report since no added personnel were assigned to the project in the seventh quarter.

In addition to the major responsibilities, above, numerous supporting personnel including managers, secretaries, purchasing agents, environmental technicians, machinists, electricians, experimental tube builders, etc., have contributed to the progress made in the first twenty-one months of the contract.

DISTRIBUTION LIST

The following pages include the distribution list supplied by the contracting officer with the approval letter for the First Quarterly Report as well as the additions authorized subsequently.

That list was utilized also for the distribution of the Second, Third, Fourth and Fifth Quarterly Reports. One deletion was made for the Sixth and this latest quarterly report.

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